

REMARKS

Applicants appreciate the Examiner's thorough review of the present application, and respectfully request reconsideration in light of the preceding amendments and the following remarks.

Claims in general

Claims 1-4 and 7-11 are pending in the application. Non-elected claims 5-6 have been cancelled. Claims 7-11 have been added to provide Applicants with the scope of protection to which they are believed entitled.

Claims 1 and 2 have been amended to better identify the claimed invention.

Specifically, claim 1 has been amended to include the added feature that the gold bump is substantially unaffected during the etching step. Support for the above feature is found in the specification at page 5, lines 29-32.

Claim 2 has been added to include the feature that TiO or TiO₂ formed on the titanium layer is removed before the gold bump is formed on the titanium layer. Support for the above feature is found in the specification at page 5, lines 15-18.

Claim 3 has been amended to be consistent with terminology used in claim 2.

Rejection of claim 1 under 35 U.S.C. 103(a) as being unpatentable over Mathew (4,922,322) in view of Li et al (6,312,830)

Amended claim 1 is directed to a method for forming a semiconductor device having a bump electrode. The method utilizes a beginning substrate having an aluminum contact pad thereon wherein at least a portion of the aluminum contact pad is exposed through a dielectric layer on the substrate. Firstly, an aluminum layer is formed on the dielectric layer and the exposed portion of the aluminum contact pad. Then, a nickel-vanadium layer is formed on the aluminum layer and a titanium layer is formed on the nickel-vanadium layer. After that, a gold bump is selectively formed on the titanium layer at a location corresponding to the aluminum

contact pad. Finally, the aluminum layer, the nickel-vanadium layer and the titanium layer are etched with the gold bump as a mask.

The method of amended claim 1 specifically requires that the gold bump be substantially unaffected during the etching step thereby obtaining a good uniformity in bump height and bump surface roughness. This significantly enhances the yield of proceeding processes. The above feature and advantage are neither disclosed, taught, nor suggested by any of the applied references.

In the method disclosed in the Mathew patent, the gold layer 16 is removed by immersing the wafer in a cyanide stripper which can effectively remove gold (see Col 3, lines 50-54); hence, at least the unprotected side surface of the gold bump 19 is exposed to the cyanide stripper. Namely, the gold bump 19 is also etched by the cyanide stripper thereby creating undesired effect (i.e., undercuts seen on FIG. 5 of Mathew) on the uniformity of bump surface roughness, which, in turn, adversely affect the quality of the gold bump. Therefore, Applicants respectfully submit that Mathew fails to disclose a step of etching the aluminum layer, the nickel-vanadium layer and the titanium layer with the gold bump as a mask wherein the gold bump is substantially unaffected during the etching step as recited in amended claim 1. Accordingly, even if the teachings of Mathew and Li were properly combinable, the resulting method would still fail to disclose or teach every limitation of amended Claim 1.

Rejection based on 35 USC § 103(a) of claims 2-4 as being unpatentable over Mathew (4,922,322) and Li et al (6,312,830), and further in view of Crafts et al (5,492,235)

For at least the above reason advanced with respect to amended claim 1, reconsideration and withdrawal of the rejection of claims 2-4 under 35 U.S.C. 103(a) are respectfully requested.

More particularly, claim 2 is patentable over the cited references not only for the reason stated above, but also for its own specific merit since Claim 2 recites a step of removing TiO or TiO₂ formed on the titanium layer before the step of forming the gold bump, which is not taught, shown or disclosed in the cited prior art. The Examiner's reliance on column 5, lines 45-50 of Crafts is deemed inappropriate because the Crafts reference does not teach or suggest cleaning

the titanium layer as presently claimed. In fact, the passage being relied upon by the Examiner teaches etching the Ti layer. See column 5, lines 50, 53 and 59-61 of Crafts.

Claims 7-9 depend from amended claim 1, and are considered patentable at least for the reason advanced with respect to amended claim 1. Claims 7-9 are also patentable on their own merits since these claims recite other features of the invention neither disclosed, taught nor suggested by the applied art. For example, the applied art of record fails to disclose, teach or suggest the etchant of claims 7-8 and the removing step of claim 9.

New independent claim 10 includes the limitation added to claim 1 and is patentable over the applied art of record for the reason advanced with respect to amended claim 1. Claim 10 is also patentable over the applied art of record because the art fails to disclose, teach or suggest the claimed step of selectively forming a gold bump on the titanium layer at a location corresponding to the aluminum contact pad, **wherein the gold bump is in direct physical contact with titanium of the titanium layer** to ensure good adhesion between the gold bump and titanium of the titanium layer. This limitation is supported at least by the specification, page 5, lines 15-18. In the Examiner's proposed combination of Mathew and Li, the gold bump is not formed in the presently claimed manner.

A prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 721 F.2d 1540, 220 USPQ 303 (Fed. Cir. 1983), cert. denied, 469 U.S. 851 (1984). *MPEP*, section 2141.02.

When the Li reference is considered as a whole, the reference specifies that it is *desirable* to treat the Ti layer (if any) in an UBM to be titanium hydride. See the claims, layer 60 in FIG. 1c, layer 85 in FIG. 2, layer 135 in FIG. 3, layer 240 in FIG. 4a, layer 240 in FIG. 4b, column 3, lines 34-36 of Li. Thus, if a person of ordinary skill in the art upon learning of the teachings by Li would have been motivated to include a layer of Ti in the structure of Mathew as the Examiner suggested, such a person of ordinary skill in the art would have *also* been motivated to treat the Ti layer as taught by Li to be titanium hydride *prior to* forming a gold bump thereon. Therefore, a proper combination of Mathew and Li would have included the step of forming a gold bump on *titanium*

hydride rather than on *titanium* as presently recited in new independent claim 10. The applied art of record therefore fails to disclose, teach or suggest all limitations of new independent claim 10.

New claim 11 is patentable at least for the reasons advanced with respect to claims 10 and 2.

Each of the Examiner's rejections has been traversed/overcome. Accordingly, Applicants respectfully submit that all claims are now in condition for allowance. Early and favorable indication of allowance is courteously solicited.

The Examiner is invited to telephone the undersigned, Applicant's attorney of record, to facilitate advancement of the present application.

Respectfully submitted,

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**MARKED-UP VERSION SHOWING CHANGES MADE
IN THE CLAIMS:**

1. (Amended) A method [for] of forming a semiconductor device having a bump electrode, the method comprising the steps of:

providing an aluminum contact pad on a substrate, at least a portion of the aluminum contact pad being exposed through a dielectric layer on the substrate;

forming an aluminum layer on the dielectric layer and the portion of the aluminum contact pad exposed through the dielectric layer;

forming a nickel-vanadium layer on the aluminum layer;

forming a titanium layer on the nickel-vanadium layer;

selectively forming a gold bump on the titanium layer at a location corresponding to the aluminum contact pad; and

etching the aluminum layer, the nickel-vanadium layer and the titanium layer [with] using the gold bump as a mask wherein the gold bump is substantially unaffected during the etching step.

2. (Amended) The method as claimed in claim 1, further comprising, before the gold bump is formed on the titanium layer, the step of [cleaning] removing TiO or TiO₂ that may have been formed on the titanium layer.

3. (Amended) The method as claimed in claim 2, wherein the [cleaning] removing step is conducted by treating the titanium layer with a cleaning medium.